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ABSTRACT

Described is a proposed structure for an elementary school science program that has as its fundamental, underlying assumption a science curriculum that enables the child to "learn how to learn" and sets self-actualized learning as a major goal of education. This program also calls for: (1) flexibility that facilitates maximum cognitive progress of individuals, a program that involves a self-determined pace; (2) instruction that facilitates individual development of interests, attitudes, personality, and creativity; (3) a program that encourages a child's tendency to accept the existence of individuals who have ideas and values which are different from his own; and (4) specification of several elements of classroom conditions that are described in sufficient detail to permit implementation in the schools for which the program is intended; these conditions can be established and maintained by the development of appropriate teacher behaviors, facilities in the classroom, and materials for children. (BR)

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STRUCTURING SCIENTIFIC KNOWLEDGE BY THE ELEMENTARY SCHOOL CHILD

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STRUCTURING SCIENTIFIC KNOWLEDGE

BY THE ELEMENTARY SCHOOL CHILD

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Introduction

Any discussion of science for the elementary school child can be facilitated by the immediate identification of the biases of the discussants. I shall reveal my biases by stating a major assumption regarding elementary school education and by making several statements of how science relates to that major assumption.

Following those statements I should like to propose a structure for an elementary school science program which is compatible with my biases and with some research activities, to which I shall refer. This proposed structure has grown out of about three years of work with children, teachers, and a variety of elementary school science activities. This work is associated with the Child-Structured Learning in Science* Project at Florida State University.

A Rationale for the Student-Structuring of Science in the Elementary School Classroom (or Some Biases and Some Research)

The fundamental assumption underlying a modern elementary school science curriculum should be:

> *"Learning how to learn" is of major importance to the elementary school child** and can be facilitated by school experiences Self-actualized learning is a major goal of education.*

Independent, self-actualized learning is characteristic of pre-school children; this pattern can be continued without interruption during the elementary

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** In this paper the "elementary school child" refers to a child who is preoperational or concrete operational. In most schools, these children will be in grades K through 6 and vary in age from 4 1/2 to 11 1/2 years.

school years for portions (if not all) of the elementary school curriculum.

The following statements relate science to the foregoing assumption:

1. A major contribution of science to the elementary school curriculum is the enhancement of the thinking of children. Developing ability to think systematically and creatively is more basic to "learning how to learn" than the traditional skills of "reading, writing, and arithmetic."

This statement does not suggest that the ability to express our ideas and emotions is not important. However, both popular and research writings are reflecting our need to put first the thoughts, the ideas, and the sensations. Then the communication becomes the tool.

In a recent popular article, William Hedgepeth comments on our inadequacies:

> So, while the framework of our language hamstrings the brain's ability to think, we cramp ourselves even more, just out of sheer perverseness. As a result, we go about transmitting at almost inaudibly low intensities with equipment that's inadequate to begin with.
>
> If words are sounds that symbolize meanings, it's obviously the meanings and not the sounds that are the things we try to get across. (1)

It is the idea--the meaning--that children should have opportunities to develop. Expression of those meanings follows the development of "the equipment"--the thinking ability. If each person is to recognize that knowledge is man-made, then each person must participate in its construction; then comes the communication.

The Educational Policies Commission of the National Education Association is responsible for the following statement regarding the development of thinking ability:

> The purpose which runs through and strengthens all other educational purposes--the common thread of education--is the development of the ability to think. (2)

After more than a quarter of a century of teaching, consulting and doing research, John Goodlad emphasizes the importance of a curriculum which places thinking first:

> If tomorrow's adults are to possess the power of rational self-transcendence, thought essential to the preservation and cultivation of mankind, then the curriculum of today's elementary schools must assure development of the full range of processes involved in the mother process, thinking. (3)

This "mother process, thinking" is most directly related to the science segment of the curriculum. Herbert Thelen puts it this way:

> Findings are science's short-range benefits, but the method of inquiry is its long-range value...The significant product of science and education will be the incorporation within the human animal of the capability and habit of inquiry. (4)

Reading is frequently identified as an important outcome of elementary school education. Reading has been defined as "...a simple process of associating printed words with their meaning; a process of getting meaning from printed material by putting meaning into it." (5) Getting meaning by putting in meaning requires, of course, that appropriate experiences have permitted the development of meanings. One researcher (6) reports that reading is enhanced in children who have developed an "analytical cognitive style," which facilitates the differentiation and analysis of certain hard-to-distinguish pairs of words (cat and bat, dog and bag, etc).

In interpreting the work of Jean Piaget, Milli Almy discusses the relationship between manipulative activity and verbal skills:

> While the vicarious is certainly not to be ruled out, it is direct experience that is the avenue to knowledge and logical ability.
>
> Language is important, but for Piaget the ability to use language to express logic is an outcome of activity. Attempts to improve the child's logic solely through instructing him in the use of language are not likely to be very successful.
>
> ...the findings in our studies of a rather substantial correlation between performance in conservation tasks and progress in beginning reading suggests that, to some extent, similar abilities are involved. A Program designed to nurture logical thought should contribute positively to readiness for reading. (6)

This "organizing principle" is based upon the notion that systematic thinking is compatible with and even enhancing to creative thinking and, furthermore, that systematic and creative thinking facilitate learning in all "areas" of human endeavor. The curriculum must encourage the natural tendency of the child to seek relationships and to make distinctions. It is not necessary to make the assumption that "thinking can be taught" or that "creativity can be taught." It is necessary to make the assumption that "thinking is developed by thinking" and that "creativity is furthered by engaging in creative activity."

2. A second important contribution of science to the elementary school curriculum is the facilitation of a positive self-concept with regard to inde-

pendent learning. Elementary school science should enhance the child's feeling of competency to identify and solve problems which make sense to him. This is brought about by providing activities in which each child is successful. Therefore, the child's success must not depend upon language skills, cognitive level, home environment, values, or other elements which give some students unnecessary advantage over other students.

"A child's self-concept of himself is built partly through seeing himself as others see him." (7) A child's self-concept is closely associated with his "cognitive, intellectual, and achievement behavior." (8) Although most Head Start Programs emphasize the improvement of the child's self-concept (7), Smilansky reported that ratings of deprived children after first grade show marked decreases as compared with a year earlier. (9)

Erikson says the danger to the beginning school child "...lies in a sense of inadequacy and inferiority...Many a child's development is disrupted when family life may not have prepared him for school life, or when school life may fail to sustain the promises of the earlier stages." (10)

John Goodlad comments on the "responsibility" of the school in avoiding the perpetuation of the "inqualities of society represented in the home." The school, he says:

> "...must provide the opportunity for a fresh start. For some children this fresh start must be provided each day until they come to realize that the behavior demanded of them out of school is not to be held against them in school. And, in time, under proper guidance, the behavior acquired in school will come to guide more and more of their behavior outside of school. If education is to be forever lifelike, our schools will never do more than mirror life around them, the best undifferentiated from the worst.
>
> Schools must strive to counter-balance much of society in providing for the most as well as the least gifted learners." (3)

The science program for the elementary school child must provide interactive experiences of the child with selected segments of his environment that have the specific advantage of increasing the child's estimation of his own worth. By making and implementing his own decisions, the child will come to recognize the extent to which he can have an impact on his environment.

The disadvantaged child frequently has difficulty with school experiences which depend upon verbal communication. In the "usual" school environment, differences in language skills associated with "social class" membership increases between first and fifth grades. (11) Ideal science materials are designed so that the child can manipulate the materials successfully with no verbal directions from the teacher. The child's verbalization is not required but develops spontaneously from his interaction with the materials. This implements the suggestion by Deutsch (11) that "curriculum change should be intro-

duced at the earliest possible time in the school experience..." to reverse the pattern of accumulative deficit as a result of "cognitive retardation" growing out of "experience deprivation."

Because the children within a classroom will represent varied levels of cognitive development, the science activities must be individualized--each child must do what makes sense to him. Because of variations in values held by children, evaluation by the teacher is deemphasized in favor of "accepting but non-evaluative teacher behaviors."

3. An elementary school science program must be flexible enough to facilitate maximum cognitive progress of individuals; this involves a self-determined pace from manipulation of concrete objects to manipulation of symbols and other abstract ideas and to the concomitant higher mental processes of problem solving. Cognitive characteristics of elementary school children dictate that all objectives of an elementary school science program must be associated with the personal manipulation of concrete objects by the learners. The emphasis on concrete objects should not suggest that elementary school science involves no abstract thinking. The child will have opportunities for "thinking" manipulations rather than doing them. This, however, will be an individual choice. He will not face the necessity of "thinking" manipulations that he cannot "hold in his mind;" he will have the option of doing.

The last decade has yielded a steady increase in research on the relationship of experience to cognitive development. Van de Geer and Jaspers (12) have pointed out that cognitive theories may vary on a continuum from extensions of stimulus-response theory to phenomenological approaches. Gray and Miller (13) have suggested that between the two extremes of this continuum lie the theoretical positions which are most influential in current research. These theoretical positions envisage cognitive growth in a way that is compatible with the science described in this paper. *Cognitive growth is the development of increasingly powerful representation systems for dealing with future encounters of the organism with reality.* This position reflects the points of view of Bruner's group (14), the Piagetian school (15), and certain of the Soviet psychologists (16).

Perhaps Bruner and his associates have been most active in making direct applications to educational theory. With regard to developing problem-solving or inquiry competencies, Bruner has written:

> Of only one thing I am convinced. I have never seen anybody improve in the art or technique of inquiry by means other than engaging in inquiry. (17)

To this idea is added the necessity for dealing with concrete realities in advance of the abstract elements of inquiry. The importance of concrete objects in a child's environment may be drawn from many theoretical positions. The critical importance for the elementary school child to have opportunities to act on and transform materials is most directly related to the theoretical position of Jean Piaget. Piaget's statement "Experience fashions reason and reason fashions experience," (18) suggests the subtle and complex relationships

between the experiences of "object manipulation" and the "idea manipulation" of higher mental processes of problem-solving.

David Ausubel admits the importance of manipulating concrete objects in an article prepared to "complement" the Piaget Conference of 1964. He writes that the emergence of simple abstractions or ideas about objects and phenomena "...must always be preceded by an adequate background of direct, non-verbal experience..." Professor Ausubel also comments on the "meaningful understanding or manipulation of relationships between abstractions or of ideas about ideas;" he writes:

> In this kind of operation the primary school pupil is still dependent upon current or recently prior concrete-empirical experience--when such experience is not available, he finds abstract relational propositions unrelatable to cognitive structure and hence devoid of meaning. (19)

If concrete object manipulation is necessary for the "normal" children, it is much more critical for the disadvantaged child who in Bloom's (20) words is "at a relatively low level of linguistic development" and "values things and activities which are concrete." The 1964 Research Conference on Education and Cultural Deprivation yielded the following analysis of the school difficulties of disadvantaged children:

> However, it is in the reduced physical activity of the school and in the demand for long spans of attention that he is at a special disadvantage as compared with children from culturally advantaged homes. It is difficult for him to learn to be quiet and to attend to a flow of words (many of which he does not understand) from the teacher. (20)

Fantini and Weinstein (21) suggest that all children are at a disadvantage in a school in which physical activity is reduced. In discussing Piaget's and Bruner's ideas and how they relate to elementary school science, Celia (Stendler) Lavatelli writes:

> Activities with a motor component are not new to science, but what is new is that we now have a rationale for which concepts need this kind of sensorimotor underpinning. (22)

This "rationale" for student-structuring of their learning comes primarily from the work of Jean Piaget. It is important to emphasize a distinction between "development" and "learning." "Development of knowledge" is recognized in Piaget's (23) words, as "a spontaneous process" which is tied to the development of the body (including the nervous system) as well as the development of mental functions. Learning, on the other hand, "...is provoked by situations..as opposed to spontaneous." Learning is limited by development only to the extent that development may not be influenced by situations. We accept the lack of conclusive information regarding the extent to which situations may influence development. Piaget iden-

tified four factors to explain development: (1) maturation, (2) experience, (3) social transmission, and (4) equilibration.

The role of "maturation" in this "rationale" is clarified by the following statements by Piaget:

> First of all, we know practically nothing about the maturation of the nervous system beyond the first months of the child's existence. We know a little bit about it during the first two years but we know very little following this time. But above all, maturation doesn't explain everything, because the average ages at which these stages appear (the average chronological ages) vary a great deal from one society to another. The ordering of these stages is constant and has been found in all the societies studied...However, the chronological ages of these stages vary a great deal. (23)

The constant ordering of these stages provides a basis for some initial assumptions on the types of "activity opportunities" that ought to be available to children. The absence of the "fine structures" of these stages emphasizes the necessity of wide variety and flexibility in "activity opportunities."

To further associate the importance of experiences with concrete objects to the theoretical position of Piaget (specifically his explanation of "development") consider the following statements made by Piaget:

> Knowledge is not a copy of reality. To know an object, to know an event, is not simply to look at it and make a mental copy or image of it. To know an object is to act on it. To know is to modify, to transform the object, and to understand the process of transformation, and as a consequence to understand the way the object is constructed. (23)

The importance of concrete objects to children of preoperational and concrete operational thought* is emphasized by Piaget in his discussion of the two types of experience--"physical experience" and "logico-mathematical experience."

> Physical experience consists of acting upon objects and drawing some knowledge about the objects by abstraction from the objects. For example, to discover that this pipe is heavier than this watch, the child will weigh them both and find the difference in the objects themselves. This is experience in the usual sense to the term--in the sense used by the empericists. But there is a second type of experience, which I shall call

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* Most children in grades K-1 are preoperational in thought; most children in grades 2-6 are concrete operational in thought.

> logico-mathematical experience, where the knowledge is not drawn from the objects, but it is drawn by the actions effected upon the objects. This is not the same thing. When one acts upon objects, the objects are indeed there, but there is also the set of actions which modify the objects. (23)

In these comments, Piaget has suggested that the child must not only have access to the objects but must manipulate them directly. The child must have direct contact with concrete objects and must learn from his "actions effected upon the objects." He expands these ideas to include language and its relationship to the source of logic:

> I believe that logic is not a derivative of language... It is the total coordination of actions, actions of joining things together, or ordering things, etc. This is what logico-mathematical experience is. It is an experience of the actions of the subject and not an experience of objects themselves. It is an experience which is necessary before there can be operations. Once the operations have been attained this experience is no longer needed and the coordination of actions can take place by themselves in the form of deduction and construction for abstract structures. (23)

Therefore, the child must have access to concrete objects which he is free to manipulate or not--as he chooses. This is based on the notion that he will manipulate the objects if they have some appeal for him and if he has not yet acquired the "operation" involved. If he has acquired the operation he will choose to coordinate his actions by "thinking" certain manipulations rather that "doing" them. He proceeds then on a "self-paced" schedule from concrete manipulations to the use "of symbols and other abstract ideas and to the concomitant higher mental processes of problem-solving." Two children working side-by-side can easily engage in their separate activities but at very different levels of sophistication in terms of abstract thinking. This is necessary if we are to serve the cognitive needs of individuals--for under these conditions it is not necessary for the teacher to know the level of intellectual development of each child, at a specific moment in time. (She could not possibly have this information.)

In addition to maturation and experience (both physical and logico-mathematical), Piaget emphasizes the importance of "social transmission" (as well as the danger of over-emphasis of this factor) in the following statement:

> This factor, once again is fundamental...but this factor is insufficient because the child can receive valuable information via language or via education directed by an adult only if he is in a state where he can understand this information... It is only when they themselves are in possession of this logical structure, when they have

> constructed it for themselves according to the developmental laws which we shall discuss, that they succeed in understanding correctly the linguistic expression. (23)

Almy adds emphasis to the dangers of heavy dependence on teacher-structured social transmission:

> Piaget's theory does not propose that a child should never be confronted with a problem that may be beyond his comprehension. But it does argue strongly that to permit him to learn an appropriate answer without making certain that he can retrace his steps, or arrive at the same result in another way, is to encourage the erection of a verbal superstructure that may crumble under even minimal cognitive stress. (6)

The fourth factor which Piaget associates with development is considered by him to be of greatest importance. Equilibration is a "process of self regulation" which provided for the learner both "feedback" and "feed-forward." Piaget says:

> ...in the act of knowing, the subject is active, and consequently, faced with an external disturbance, he will react in order to compensate and consequently he will tend towards equilibrium. Equilibrium, defined by active compensation, leads to reversibility. Operational reversibility is a model of an equilibrated system where a transformation in one direction is compensated by a transformation in the other direction. Equilibration, as I understand it, is thus an active process. (23)

The four factors, maturation, experience, social transmission, and equilibration, affect the "development of knowledge" in the child and have implications for school programs for the child. These implications can be summarized briefly as follows:

a. Maturational "stages" occur in a definite sequence but vary in "age of appearance" from one child to another. Self-paced activity by the child is, therefore, critical.

b. Experience with concrete objects is necessary both from the standpoint of learning from the objects, and learning from what is done to the objects by the child.

c. Social transmission (talking to children) is useful only to the extent that the child already possesses the structure necessary for understanding. The teacher must, therefore, talk with the child about what the child is doing rather than what she would like the child to "know." The teacher must talk cautiously with children, ready to recognize the

absence of the structure which permits understanding, willing to await this self-structuring by the child.

d. Equilibration requires active involvement by the child. It requires individual reflection and activity. The teacher must not interfere by forcing her structures verbally or by demonstration on the child. "Time to think" must be generously available to children--but objects on which to act and think must also be generously available.

4. An elementary school science program must facilitate *individual* development of interests, attitudes, personality and creativity which enhance the continued development of individuality in the learner. Each student must have the opportunity to develop those unique abilities which increase his self-respect and independence. Each student must have the opportunity to develop his creative abilities.

According to Guilford (24) education has concentrated too much on convergent thinking; it has taught the student how to reach answers which society has determined to be "correct." Except possibly in the arts, critical thinking has been restricted to a framework in which every question has one correct answer.

George Kneller levels the charge against our educational system that it has:

> ...neglected, and all too often suppressed, the natural creativity of the young...for only in the last decade have educators begun to realize that creativity is as natural to the average student as it is to the genius. (25)

Abraham Maslow writes of the "newer humanistic paradigm" for science. He sees this as activity in which:

> ...the more everyday cautions and patient work of checking, validating and replicating is seen, not as all there is to science but rather as follow-up work subsequent to the great intuitions, intimations, and illuminations of the creative and daring, innovative, break-through scientist. Caution is then seen to follow upon boldness and proving comes after intuition. (26)

In summarizing Piaget's contribution to the 1964 Conference on Cognitive Studies and Curriculum Development, Eleanor Duckworth emphasized the implications of his approach for educational practices:

> The great danger today is from slogans, collective opinions, ready-made trends of thought. We have to be able to resist individually, to criticize, to distinguish between what is proven and what is not. So we need pupils who are active, who learn early to find out by themselves partly by their own spontaneous activity and partly through material we set up for them; who learns early to tell what is verifiable and what is simply the first idea to come to them. (27)

It is this aspect of science that causes it to be a powerful segment of the elementary school curriculum. This aspect provides the motivation to use science in the elementary school to enhance the development of the unique abilities of children from varied backgrounds--children who are different from each other. Educational attention to "individual differences" can become more than abstract "lip service."

Ottinger and Marks call our attention to a 1967 statement by Glen Heathers:

> During the past decade, the term "individualizing instruction" has become a watchword with educational reformers. Two recent yearbooks of educational organizations have had this term as title...oddly both volumes were written as though everyone knows what individualization means since neither of them offers a working definition of the term. In point of fact, there is great confusion. (28)

The approach to individual differences which seems most likely to enhance the self respect, independence, and creativity of the individual depends heavily upon the accessibility to the child of appropriate sets of objects under appropriate conditions. These materials and conditions must make possible a great variety of activities--activities which each child can voluntarily and independently design for himself. The properties and property relationships represented by the objects must be related to the cognitive characteristics of the child and must have sufficient appeal that he chooses to "work with" them.

5. An elementary school science program should encourage a child's tendency to accept the existence of individuals who have ideas and values which are different from his own. The elementary school science program whould facilitate the recognition of the uniqueness of individuals, their ideas, their values, and their behavior patterns without the usual heirarchical ranking of those individuals. The child should learn to disagree on ideas and to defend his own ideas without the usual conclusion that the opposing idea (or the opposing individual) is wrong, stupid, or otherwise inferior.

This is compatible with preceding statements about the nature of science. Alternative explanations for phenomena are accepted in science. Alternative statements of perceived relationships are not necessarily contradictory.

An elementary school science program will enhance "acceptance without evaluation" of differences by the daily reflection of this in the behavior of the teacher and the children. Accepting differences is necessarily associated with a program which enhances the development of differences.

6. An elementary school science program is specified only when the several elements of classroom conditions have been described in sufficient detail to permit implementation in the schools for which the program is intended.

A variety of definitions for "curriculum" can be found in curriculum

writings. I agree with Taba (29) that--"some definitions are too all-encompassing and vague to help precision in thinking." However, development of an appropriate elementary school science program rules out as too narrow the specification by Gagne (30) that curriculum "...leaves out specific consideration of the design of learning conditions." Curriculum research can be done only to the extent that the curriculum can be reproduced. (31) This is possible only if all necessary elements of the curriculum have been described and if means of establishing and maintaining those conditons are available.

Classroom conditions for science may be described in terms of (a) physical facilities, (b) materials for children, and (c) teacher behaviors. The program exists only to the extent that these three components of classroom conditions are compatible with the program goals.

Although no conclusive research data is available to specify precise conditions under which learning is maximized, we are not left without strong indications of the sets of conditions which are associated with different outcomes of education. Undoubtedly, the largest "body" of research relating to classroom conditions is that research commonly referred to as "classroom interaction analysis" or "systematic classroom observation." This field of research has been extremely valuable because it has operationally defined "teaching" and "learning" as different activities. It has, instead, attempted with considerable success to empirically associate certain "teaching behaviors" with certain "learning behaviors," or "outcomes of education." Various researchers have been impressively successful in identifying these "associations," or relationships.

B. O. Smith's early work with "closed episode" versus "open episode" teaching, for example, lead to the following conclusion:

> It is not difficult to see that episodes of the closed type lend themselves very easily to programmed instruction such as that used in so-called teaching machines where the situations are so structured as to reduce the chance of incorrect responses. In sharp contrast, episodes of the more open forms lend themselves to manipulation by those teachers who wish to encourage originality and flexibility in their students. It seems reasonable to suppose that the openness of episodes tends, in the various sciences, to encourage creativity and, in those fields with social concerns, to stimulate the growth of wisdom. (32)

If rationality is as Rogers (33) defines it, "the use of the most effective means to reach a given end," then the science program will employ "open episodes," which "encourage a great variety of responses," (32) as opposed to the "closed episodes," which involve only one correct response.

The earliest systematic studies of "classroom climate" are those of Anderson and his colleagues (34, 35, 36, 37). These studies of preschool and elementary school classrooms involved different teachers and extended over several years; they revealed that the teacher's behavior set a pattern which spread

throughout the classroom--influencing the behaviors of children even when the teacher was not present. These student behaviors even persisted into the following school year. If the teacher dominated, the students adopted dominating behaviors; if the teacher was integrative, so were the children. Anderson's studies also revealed that initiative, spontaniety, and problem-solving were enhanced by integrative teacher behavior. The students of dominative teachers were more easily distracted from schoolwork and showed greater compliance to, as well as rejection of, teacher domination.

A rational decision is to establish and maintain integrative teacher behaviors, or those behaviors which increase the alternatives of children--behaviors which do not command children. These conclusions were supported in the independent investigations of Lippett and White (38).

Flanders (39) found that dominative teacher behaviors were consistently disliked by pupils, reduced their ability to recall, and produced disruptive anxiety revealed in galvanic skin response and changes in heart beat rate. Perkins (40) found that greater learning took place if the teacher used integrative techniques; Cogan's work (41) even revealed that students did more assigned and extra schoolwork when they perceived their teacher's behavior as integrative.

Lewin has found that "objectivity cannot arise in a constraint situation; it arises only in a situation of freedom." (42) *Constraint teacher behaviors produced a high level of dependency of students on their teachers.*

This powerful work of Anderson has been pursued by many "followers" into the current research of Withall, Joyce, Flanders, and many others who followed the Flander's "model". The 1968 "Anthology of Classroom Observation Instruments," repeats and emphasizes the composite findings of the last thirty years of research on classroom teacher behaviors:

> Teachers who behave in an integrative (supportive) fashion tend to have students who behave integratively, and conversely, dominative teachers have students who are dominative, aggressive, and non-sharing." (43)

"Goal clarity" was introduced by Flanders (44). His research suggests that dependency does not increase in students if the instructional goals are clear to them--even when the teacher exerts "direct influence" over the activities of students. However, *if the goals are not clear to students, a high level of dependency developes when teachers are "directive."*

These findings have clear implications for science classroom conditions--*since the goals of an elementary school science program cannot possibly be clear to the students.* A student who does not have a concept of classification cannot possibly understand a goal which involves developing a concept of classification. A student who does not understand iteration cannot possibly have an understanding of a goal which involves measurement of length with a ruler. Therefore, it seems uncompromisingly clear that classroom conditions must involve freedom of the student to choose and direct his own activities. The teacher must not tell or show the student how to do the activity--nor

even tell him which activity to do. This imposes severe, but challenging, limitations on the materials which may be designed for children. The child must have a spontaneous affinity for the materials! The science concept and process objectives must be communicated to the child via his own interpretations of and actions on the sets of objects which are available to him.

Since different children will have affinities for different materials and will have different cognitive levels, there must be a variety of objects available and there must be a variety of "activity opportunities" with each.

A Program to Facilitate the Student-Structuring of Science in the Elementary School Classroom (or Letting the Child Do His Own Thing)

A. Objectives

A beginning science program should have objectives associated with both affective and cognitive learning. The cognitive objectives should be associated with the goal of communicating to children what science is and how creative and systematic thinking relates to solving self-perceived problems. *The child who completes a K-6 science program should be able to design activities (without suggesions) and do activities (without instructions) in which he: (1) manipulates objects in a way that is dependent upon the properties of the objects, (2) identifies relationships among the properties of "static objects" or among the factors which affect the behaviors of "dynamic systems," and (3) manipulates objects to test the usefulness of the relationships which he has identified.*

The affective objectives should be associated with the development of a positive self concept with regard to independent learning. *The child who completes a K-6 science program should identify himself as a person who can be successful in science and who chooses to use science. He should describe science in terms of activities which make sense to him. He should state his own explanations for natural phenomena and should modify these only when they cease to be compatible with his own interpretations of his environment. He will frequently state alternative explanations for an observed phenomenon and will identify "tentativeness" as an important characteristic of scientific knowledge.*

Science can be communicated to students by activities in which students engage. These activities must be consistent with "what science is" and "the child's perceptions." If the program which the child associates with science is a program in which science facts, science concepts, or science processes are given to the student, then the student learns that science is a collection of facts, concepts, or processes. This learning is reinforced if he is then asked to repeat back to those facts or concepts on an examination or to exhibit those process skills in which he has been trained. Clearly, many school science programs involve predominantly this kind of activity.

If one intends to communicate rational science then the school science program must involve students who are participating with their minds and their hands

in science. This participation must make sense to them at the time they are participating. The student participant in science must seek relationships during science activities. He must decide whether or not he has identified a relationship and must assess for himself the value of that relationship as a piece of scienctific knowledge. Thus, science can be communicated to the student participant by providing activities appropriate to that which is to be communicated. *Science is communicated to a student by having the student participate in science which makes sense to him at the time of participation.*

B. Classroom Conditions

In designing an elementary school science program one must make the assumption that the environment for learning communicates both cognitive and affective messages. *Conditions must be established so that the cognitive message makes sense to the child and the affective message facilitates an affinity for independent decision-making and a positive self concept with regard to science.* Each child should frequently (probably daily) participate in a "science session" which is characterized by the following classroom conditions:

1. *Each child should have access to his own set of materials.*

   Children should be permitted to share but not required to share materials. It is critical that children feel relaxed and independent as they engage in science activities. One child should not be under pressure to keep up with another child. Primary school children characteristically choose to work individually if given a choice. Older children frequently work in groups. Children should have the responsibility of deciding on the size of the group.

2. *Each child should feel that he can do what he wishes with the materials (including doing nothing) so long as he does not disturb other children or damage his materials.*

   Since the teacher or curriculum designer cannot be sure of what makes sense to an individual child and since science is "using one's mind and hands in a way which makes sense" it is necessary that the child decide what he is to do with the materials available to him. The careful selection of objects by the curriculum developer provides the child with opportunities for engaging in a great variety of activities. A "science session" will terminate for a child when he decides he has "finished." (Of course, it might be necessary for the teacher to terminate a session because of time limitations beyond her control.) A child should never feel compelled to continue with a set of materials because other students have not "finished."

3. *After receiving "new" materials, the child may elect to return to an "old" set.*

   Previously-used materials are available at the "side table"--an

important part of the science program. Children are permitted to use any material at the "side table" during "free" time throughout the school day. "Access" is of critical importance!

Vertical and lateral flexibility is provided by the continued availability of materials at the "side table." The child must feel confident that he can decide for himself how much time he will devote to a particular set of materials. He must not be afraid of "losing" access to materials when he gives them up for the day.

These classroom conditions can be established and maintained by the development of appropriate teacher behaviors, facilities in the classroom, and materials for children. Teacher behaviors for this science program can be described in quantitative terms by the use of an instrument (45) developed for this purpose. The following statements describe teacher behaviors in qualitative terms:

1. *The teacher will respond to what the individual child is doing rather than giving a generalized response to all children.*

   This means that the teacher will interact verbally with individual children (or with small groups) rather than with the entire group of children. A well-accepted educational trend is toward "individualized instruciton." Various forms of "individually prescribed instruction" and "contract teaching" are being revived or introduced. These "techniques" have frequently been applied to existing curricula with few sound criteria for answering questions like the following: On what basis does one individualize science activities for young children? What characteristics of a child provide the "input" for his individual "prescription?" Are the program objectives compatible with the intellectual abilities of the child?

   In a science program the teacher should take a humanistic approach to individualized learning. Note that the teacher *responds* to, rather than directs, the child's behavior during science activities.

2. *The teacher will probe (without pressure) the child's thinking in order to give the child opportunities for verbalization.*

   The teacher plays an active role during "science session," but she does *not* control the activities of children by giving directions on how activities should be done. Neither does she direct the activities by asking specific questions for which the child feels obligated to find answers. A child must be comfortable in saying, "I don't know." The teacher must not only communicate this verbally but must behave as if she means it.

3. *The teacher must reward children equally for their activities.*

   She cannot praise the child who classifies by placing objects in piles and ignore the child who makes a "picture" with the same

objects. To implement this, it is suggested that the teacher exhibit "accepting" but "non-praising" behaviors in response to students.

The teacher must not communicate certain "expected behaviors" as the "correct behaviors;" this could place the child under pressure to exhibit behaviors which do not make sense to him. One must not reason: If this is the behavior that is desired in the child, then efficiency demands that we show or tell the child how to exhibit the behavior and, thereby, bring him quickly to success (as defined by the adult). This practice can and does result in much drill in verbal and manipulative mimicry by the child. Even worse is the strong likelihood that the child learns that science is mimicry--or that learning is mimicry.

It *might* be necessary for the teacher to praise children for *social behaviors*, but she should not communicate that certain science activities are better than others. This would result in an immediate reduction of the freedom of the child to implement *his own* ideas.

4. *The teacher must accept (but not reinforce) the child's "erroneous" statement and must not tell him what he does not understand.*

   If one concerns himself with both the cognitive and the affective elements of communication, then the problems associated with "telling" and "correcting" become undeniable. Consider the child who says after "hefting" that one object weighs more because it is bigger. The teacher corrects him by saying "try that again." The affective element of that communication might be: "Don't depend upon your own perceptions. Depend upon the teacher's clue" or "Your teacher thinks you're not very bright." This affective element could very well override the cognitive element of the communication--especially if the child has no functional concept for weight, volume, surface area, etc. This creates a critical problem in the natural sciences--an area in which the child should definitely turn to his natural environment for answers to his questions.

   It is accepted that children can learn to say words which have little meaning for them. The six-year-old can talk of molecules, energy, gravity, and mass. The notion that his verbal definitions for these terms make useful sense to him can be dispelled by the teacher who questions the child without leading him (giving him more words to say). The scientific illiteracy of most adults suggests that the cognitive element of the communication in their science "courses" was nonsense. Their dislike for science suggests that the affective element of the communication was negative.

   Consideration of this point of view requires the teacher to

> consider the danger of the verbal teaching of "ideas" which the child cannot understand because his level of cognitive development does not permit the understanding. The teacher recognizes the danger of "training" the child to participate in non-verbal activities before he has access to mental operations associated with these activities. A child who does not have access to mental operations associated with identifying and controlling variables in an investigation can be "trained" to do this. He can mimic others or follow step-by-step suggestions. Is it not extremely likely that the child will "learn" these "activities of science" within a nonsense framework? Will the child learn that learning nonsense is "okay"--or even necessary? Is it desirable that his initial experiences with science involve the learning of nonsense on the assumption that it will someday make sense to him?

Physical facilities should provide maximum freedom of movement for children and maximum "working space" for individuals or groups of children. This working space should be a flat surface--ideally a tabletop but floor space is adequate. Since a large number of sets of objects must be accessible to children, a "side table" is a necessary piece of furniture for the display of these sets of objects.

C. Content

The "content" of the elementary school science program may be described in terms of (1) materials, (2) concepts, (3) processes, and (4) information.

1. Materials

> In accordance with the variation in cognitive characteristics of children from 4 1/2 years to 11 1/2 years of age (grades K-6), the characteristics of sets of objects will vary. Certain requirements on the sets of objects are imposed by the classroom conditions necessary to implement the program objectives. Since the teacher cannot require children to "work with" materials, it is necessary that children have a voluntary affinity for them. The emphasis for preoperational children will be on static sets of objects which possess properties and property relationships related to concepts, processes, and information considered appropriate to the interests and cognitive levels of the children. As children advance into the stage of concrete operations, materials will be presented as dynamic systems which facilitate the perception of various behaviors of the systems and ways of manipulating these behaviors. In some cases systems will be presented to children for their investigation; in other cases materials will be available from which children might construct dynamic systems, which they then might investigate.

2. Concepts

> Concepts are associated with materials in that they must be communicated

to children by their interpretation of properties, property relationships, and behaviors of objects. Concepts are planned in accordance with the cognitive potential of children. For example, concepts such as number, length, area, color, shape, and texture are associated with sets of objects for children in grades K-2. Action on objects might introduce concepts such as classifying, ordering, and measuring.

It is anticipated that concepts will develop from simple properties toward property relationships and from property relationships toward problem-solving. It is not clear at what rate this development will take place. Research does not yet reveal the extent to which 11-to-12-year-old children might be expected to have available the mental operations associated with scientific problem-solving.

3. Processes

Processes are associated with materials and concepts in that they must become available to children as a result of their own perceptions of the materials and the mental operations possessed by the children. Children will not be "trained" to engage in processes such as classifying, ordering, measuring, and controlling variables. They will have opportunities to engage in processes as they perceive the desirability of engaging in these processes. It should be emphasized that the separation of "concepts" and "processes" in this paper is for convenience and clarity of communication. In the development of a program concepts and processes do not have separate identities. "Process" is viewed as a concomitant action associated with the self-structuring of "concept."

4. Information

The communication of information to children should not be of independent concern in an elementary school science program. It is included under "content" because communication of information cannot be avoided (and, of course, no one wishes to avoid it). Children who interact with science materials will acquire information in a meaningful framework of activity--both physical and mental.

D. Teacher Preparation

Although it is beyond the scope of this paper to describe a teacher preparation program, a few comments are in order. Teachers teach as they are taught! Learners behave as do their teachers. This in an observation which has been verified by research (28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39); it has important implications.

In an elementary school science program, the child should be provided with classroom opportunities for structuring his own knowledge by the utilization of mental processes which are available to him. These mental processes are associated with physical manipulations of concrete objects in the environment. Ob-

viously, the physical manipulation is of very little (or no) value if the child follows the instructions of his teacher or mimics the behavior of another child. The child must manipulate objects because he recognizes some "sense" in the manipulation. For example, it is assumed that the child who puts circular objects into one group and square objects into another after having been told to do so is engaging in a very different activity from the child who groups objects because he has some self-identified reason for grouping the objects. It is obvious that the science program for children would be seriously impaired if children were told or shown what to do with the materials of the program. It is equally likely that the effectiveness of the program for children would be seriously impaired if the objectives associated with the program are communicated *verbally* to teachers prior to the teachers' physical and intellectual interaction with the materials and activities associated with the program. Operationally, this means that the teacher must be provided with experiences similar to those experiences which are provided for children. For example, the teacher must recognize objects. If the importance of classification and the physical manipulations associated with the classification activities are verbally communicated to teachers, it is almost certain that teachers will at some point communicate this verbally to children.

This suggests that science teaching cannot be taught to teachers by telling them about the science program. To tell the teachers would be equivalent to telling the children--for telling teachers communicates that teachers should tell the children. It is critical that this pattern be avoided. *It is imperative that the elementary school teacher structure for herself the meaning of the science program.* This requires the careful development of materials which are as appropriate for the teacher as the child's materials are for him. These materials for the teacher and the activity opportunities provided for the teacher constitute a "teacher preparation program". [A more complete description of a teacher preparation program which is compatible with the structur of scientific knowledge by children will be available in January, 1971 (46)].

Conclusion

If science is the human activity of making sense of the environment as one interprets it and if elementary school children perceive their environments differently, then any appropriate elementary school science program will maximize the importance of the individual child in the program. Any appropriate program will minimize the importance of "identical learning" and will make no effort to implement "identical learning on an identical schedule."

The science experiences of most elementary school children are leaving the impression that science is merely a collection of facts, laws, and static generalizations which are usually feared or dreaded by the non-scientist. In recent years "discovery" approaches to teaching and learning science has received increasing emphasis in connection with the development of elementary school science programs. Words like "inquiry," "invention," and "open-endedness" have been revived or introduced into current dialogue on science teaching. Instructional techniques which involve predominantly verbal transmission of ideas are being abandoned (or at least questioned). This has resulted in elementary school science programs which emphasize *activities* of science. Emphasis on the

"facts" of science is being balanced by greater emphasis on the "processes" of science.

A beginning science program which takes into account the child's interpretation of his environment and which defines science in terms of "identification of logical relationships" is compatible with the trend toward emphasis on student activity, discovery, processes of science, etc. However, merely shifting emphasis from "products" to "process" does not necessarily result in a science program which makes sense to children. Merely shifting the child's role from passive consumer of "facts" to active participant in activities does not make science rational for the child. This is especially true if we insist that the children exhibit performance behaviors which are merely mechanical exercises in which they mimic the teacher or other children.

REFERENCES

1. Hedgepeth, William, "We Need New Ways to Say What's Real," Look, January 13, 1970.

2. The Central Purpose of American Education, National Education Association, Educational Policies Commission, Washington, D.C.; 1961.

3. Goodlad, John I., School Curriculum and the Individual, Blaisdell Publishing Co., Waltham, Massachusetts; 1966.

4. Thelen, Herbert A., Education and the Human Quest, Harper & Row, New York, Pg. 217; 1960.

5. Breckenridge, Marian E. and Vincent, E. Lee, Child Development, W. B. Saunders Company, Philadelphia; 1965.

6. Almy, Millie, Young Children's Thinking, Teachers College Press; New York; 1966.

7. Smart, Mollie S. and Smart, Russell C., Children: Development and Relationships, MacMillan Co., New York; 1967.

8. Office of Economic Opportunity, Review of Research 1965 to 1969, (Prepared by Project Head Start), OEO Pamphlet 6/08-13, June, 1969.

9. Smilansky, Sarah, "Evaluation of Early Education," UNESCO, Educational Studies and Documents, No. 42, 1961.

10. Erikson, E. H., Childhood and Society, W. W. Norton and Co., Inc., New York; 1950.

11. Deutsch, Martin, "The Role of Social Class in Language Development and Cognition," American Journal of Ortho-psychiatry, 35; January, 1965.

12. Van de Geer, John P., and Jaspers, Joseph, "Cognitive Functions," Annual Review of Psychology, (Edited by Farnsworth, McNemar, and McNemar.) Annual Reviews, Palo Alto, California; Vo. 17, 1966.

13. Gray, Susan W. and Miller, James O., "Early Experience in Relation to Cognitive Development," Review of Educational Research, Vol. 37, No. 5, December, 1967.

14. Bruner, Jerome S., et.al. Studies in Cognitive Growth: A Collaboration at the Center for Cognitive Growth, John Wiley & Sons, New York; 1966.

15. Inhelder, Barbel, "Operational Thought and Symbolic Imagery," European Research in Cognitive Development, Monographs of the Society for Research in Child Development, (Edited by Paul H. Mussen.) University of Chicago PREss, Chicago; Vol. 30, No. 2, 1965.

16. Zaporozhets, A. V., "The Development of Perception in the Preschool Child," European Research in Cognitive Development, Monographs of the Society for Research in Child Development, (Edited by Paul H. Mussen.) University of Chicago Press, Chicago; Vol. 30, No. 2, 1965.

17. Bruner, Jerome S., "The Act of Discovery," Harvard Educational Review, Vol. 33, No. 1, Winter, 1963.

18. Piaget, Jean, The Child's Conception of Physical Causality, (Translated by Marjorie Gabain.) Littlefield,Adams and Co., Totowa, New Jersey; 1966.

19. Ausubel, David P., "The Transition from Concrete to Abstract Cognitive Functioning: Theoretical Issues and Implications for Education," Journal of Research and Science Teaching, Vol. 2, Issue 3, 1964.

20. Bloom, B. S., Davis, A., and Hess, R., Compensatory Education for Cultural Deprivation, Holt, Rinehart, and Winston, Inc., New York; 1965.

21. Fantini, Mario D. and Weinstein, Gerald, The Disadvantaged: Challenge to Education, Harper & Row, New York; 1968.

22. Stendler, Celia, The Developmental Approach of Piaget and its Implications for Science in the Elementary School, The McMillan Co., New York; 1966.

23. Piaget, Jean, "Development and Learning," Part I of "Cognitive Development in Children," Journal of Research in Science Teaching, Vol. 2, No. 3, 1964.

24. Guilford, J. P., Personality, McGraw Hill, New York; 1959.

25. Kneller, George F., The Art and Science of Creativity, Holt, Rinehart, and Winston, Inc., New York; 1966.

26. Maslow, Abraham H., "Some Educational Implications of the Humanistic Psychologies," Harvard Educational Review, Vol. 38, No. 4, Fall, 1968.

27. Duckworth, Eleanor, "Piaget Rediscovered," Journal of Research in Science Teaching, Vol. 2, No. 3, 1964.

28. Oettinger, Anthony and Marks, Sema, "Educational Technology New Myths and Old Realities," Harvard Educational Review, Vol. 38, No. 4, Fall, 1968.

29. Taba, Hilda, Curriculum Development - Theory and Practice, Harcourt, Brace & World, Inc., New York; 1962.

30. Gagne, Robert, "Curriculum Research and the Promotion of Learning," Perspectives of Curriculum Evaluation, AERA Monograph Series on Curriculum Evaluation, Rand McNally & Co., Chicago; 1967.

31. Popham, W. James, "Curriculum Materials," Reviews of Educational Research, Vol. 39, No. 3, June, 1969.

32. Smith, B. O., "Toward a Theory of Teaching," Theory and Research in Teaching, (Edited by Arno A. Billack), Bureau of Publications, Teachers College, Columbia University, New York; 1963.

33. Rogers, Everette M., Diffusion of Innovations, The Free Press, New York; 1962.

34. Anderson, Harold H., "The Measurement of Dominative and of Socially Integrative Behavior in Teachers' Contacts with Children," Child Development, Vol. 10, No. 2, June, 1939.

35. Anderson, Harold H. and Brewer, Helen M., Studies of Teachers' Classroom Personality, I: Dominative and Socially Integrative Behavior of Kindergarten Teachers, Applied Psychology Monographs, No. 6, 1945.

36. Anderson, Harold H. and Brewer, Joseph E., Studies of Classroom Personalities, II: Effects of Teachers' Dominative and Integrative Contacts on Childrens Classroom Behavior, Applied Psychology Monographs, No. 8, 1946.

37. Anderson, Harold H., Brewer, Joseph E., and Reed, Mary Frances., Studies of Teachers' Classroom Personalities, III: Follow up Studies of the Effect of Dominative and Integrative Contacts on Childrens Behavior, Applied Psychology Monographs,No. 11, 1946.

38. Lippitt, R. and White, R. K., "The Social Climate of Childrens' Groups," Child Behavior and Development, (Editors - R. G. Barker, J. S. Kounin, and H. F. Wright), McGraw Hill, New York; 1943.

39. Flanders, Ned A., "Personal-Social anxieties as a Factor in Experimental Learning Situations," Journal of Educational Research, Vol. 45, October, 1951.

40. Perkins, H. V., "Climate Influences Group Learning," Journal of Educational Research, Vol. 45, October; 1951.

41. Cogan, M. L., "Theory and Design of a Study of Teacher-Pupil Interaction," Harvard Educational Review, Vol. 26, No. 4, Fall; 1956.

42. Lewin, Kurt, Dynamic Theory of Personality, McGraw Hill, New York; 1935.

43. Mirrors for Behavior, An Anthology of Classroom Observation Instruments (Edited by Anita Simon and E. Gil Boyer) Classroom Interaction Newsletter, Research for Better Schools, Inc., Philadelphia, Vol. 3, No. 2; 1968.

44. Flanders, Ned A., "Teacher Influence in the Classroom," Paper Presented at the First Teachers College Conference on Research and Theory in Teaching, April 13-14; 1962.

45. Matthews, Charles C. and Phillips, Darrell G., Handbook for the Application of the Science Curriculum Assessment System, Florida State University, Tallahassee, Florida; 1968 (mimeographed).

46. Matthews, Charles C., Phillips, Darrell G., and Good, Ronald G., Student-Structured Learning in Science-A Program for the Elementary School Teacher, W. C. Brown Co. Publishers, Dubuque; 1971.